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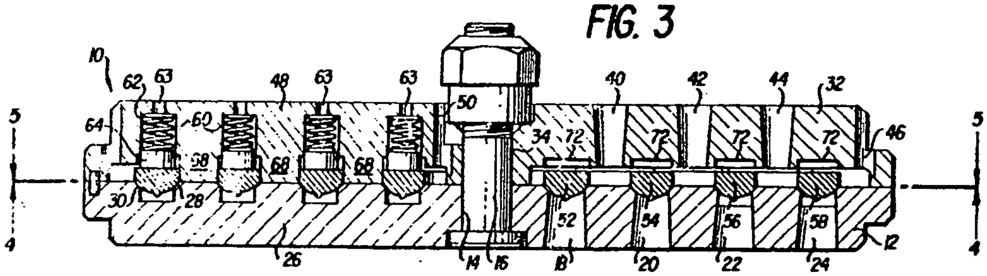
(54) Improved compressor valve having annular valve elements

(57) An improved compressor valve structure is disclosed, of the type in which one or more annular valve elements (52, 54, 56, 58) seal against annular seating surfaces (28, 30). The valve elements are biased into contact with their seating surfaces by resilient means (60, 64) which also cooperate with the neighboring valve guard structure (62, 63, 72) to fluidically dampen movement of the valve elements once they have left their seating surfaces. A curved contact element (64) between the valve elements and their retaining springs (60) allows the valve elements to flex or roll as necessary to accommodate differential thermal expansion of the valve seat, valve guard and valve elements so that effective sealing still can be achieved. The valve elements include a flow balancing ridge (82) on their high pressure sides, to direct fluid flow more evenly to both sides of the annular valve elements.

FIG. 3



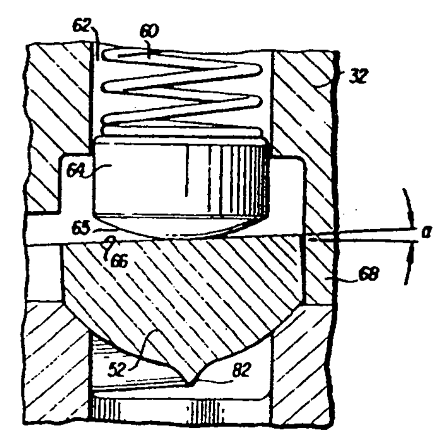


FIG. 8

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FIG. 1

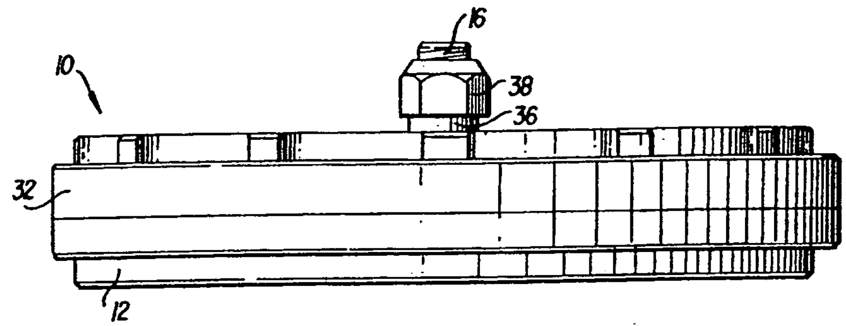

FIG. 2

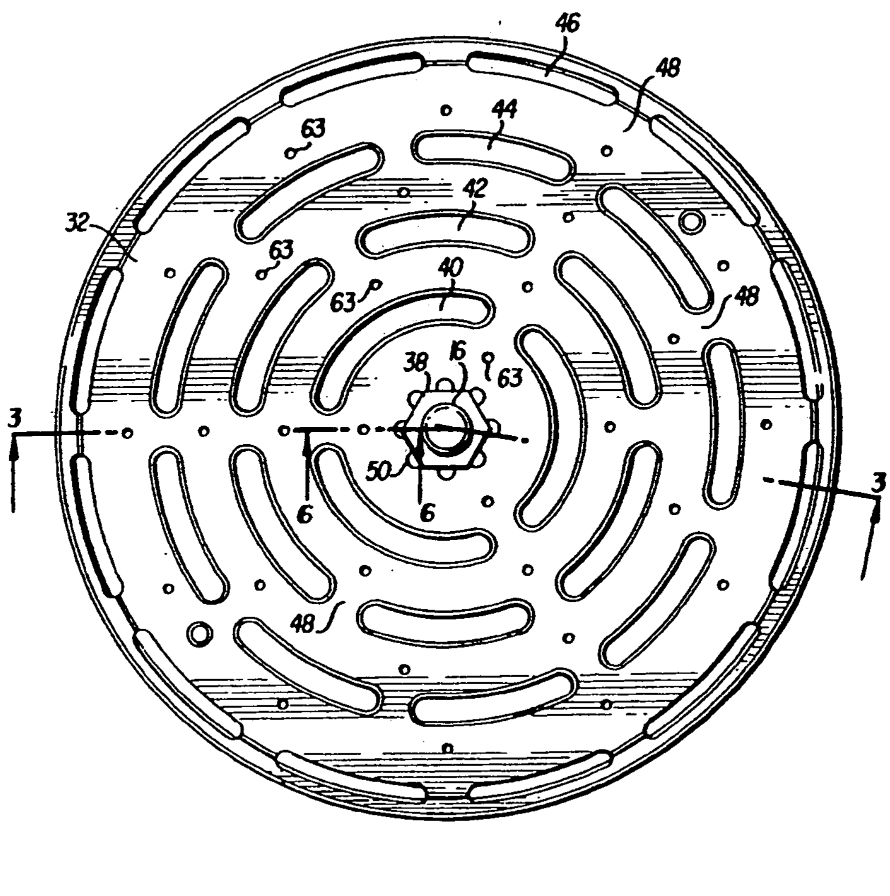

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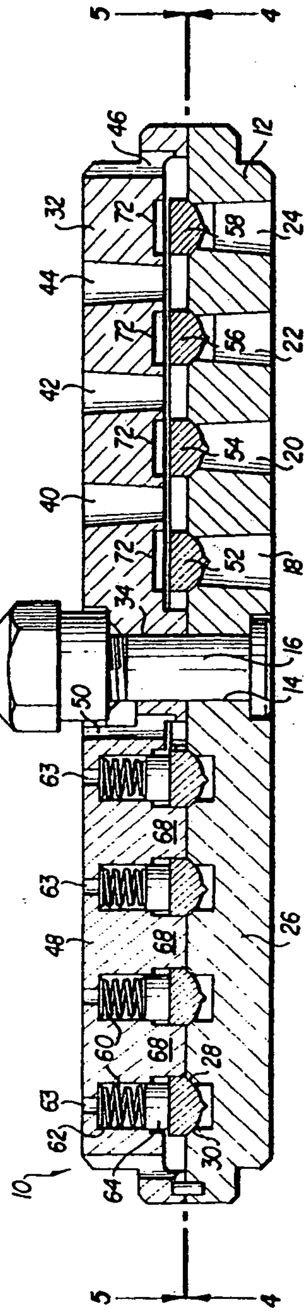
FIG. 3



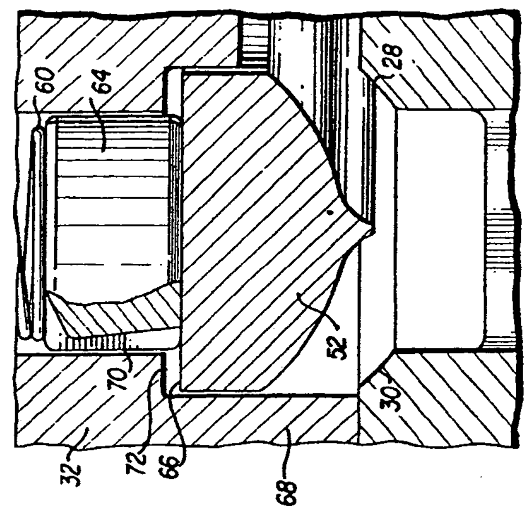


FIG. 6B

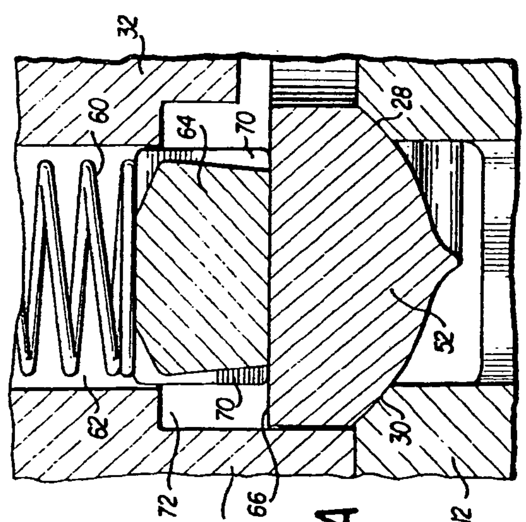


FIG. 6A

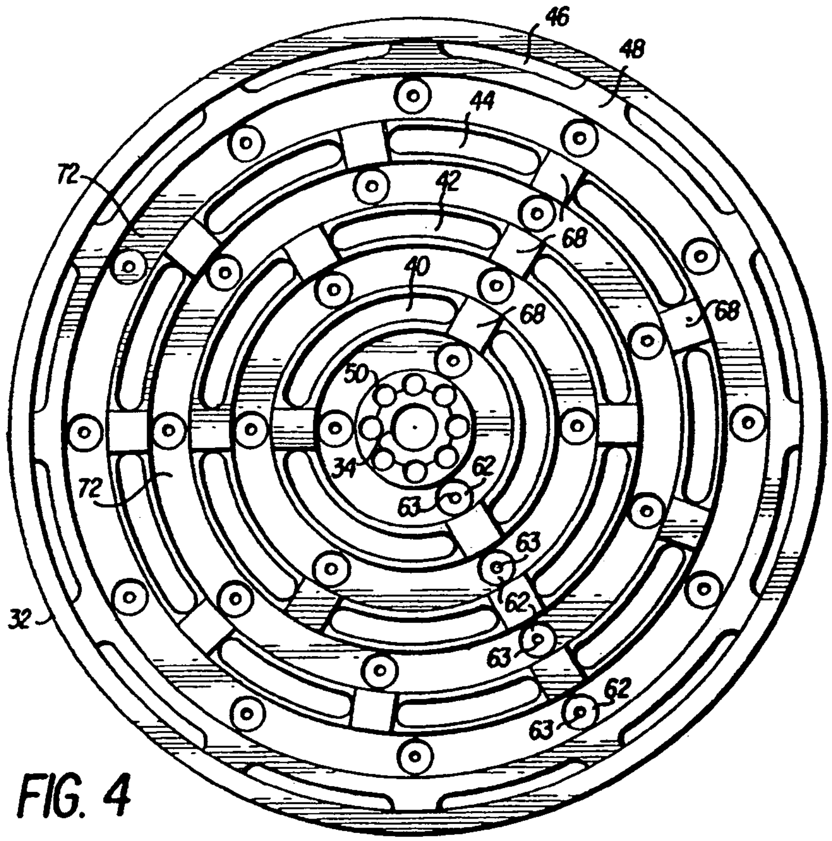


FIG. 4

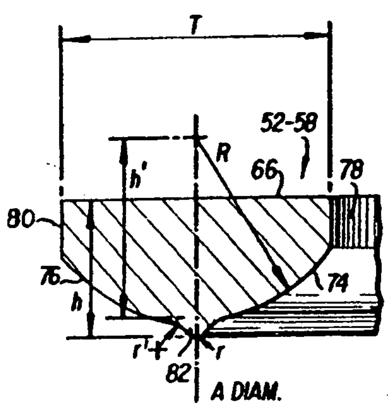


FIG. 7

TYPE	A	O.D.	I.D.	No. SPRINGS
1	40.0mm	52.0mm	28.0mm	3
2	80.0mm	92.0mm	68.0mm	6
3	120.0mm	132.0mm	108.0mm	9
4	160.0mm	172.0mm	148.0mm	12
5	200.0mm	212.0mm	188.0mm	15

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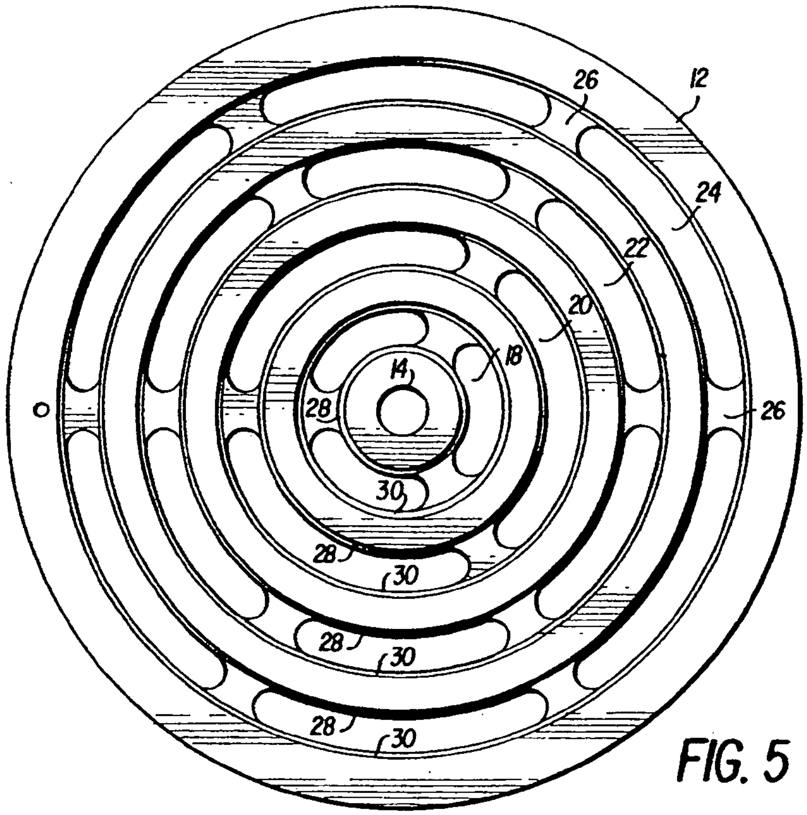


FIG. 5

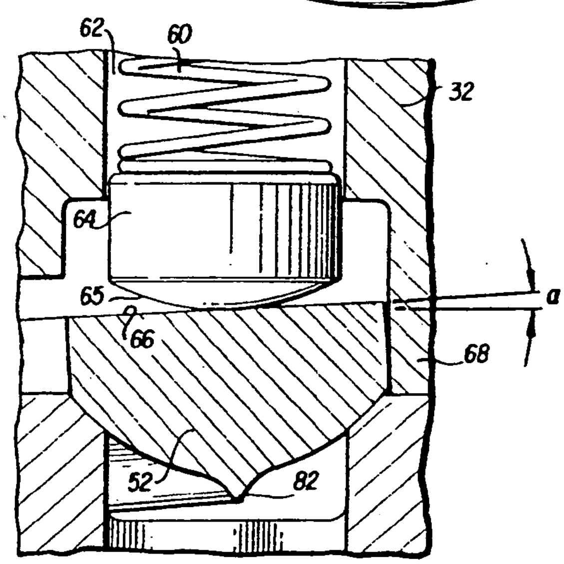


FIG. 8

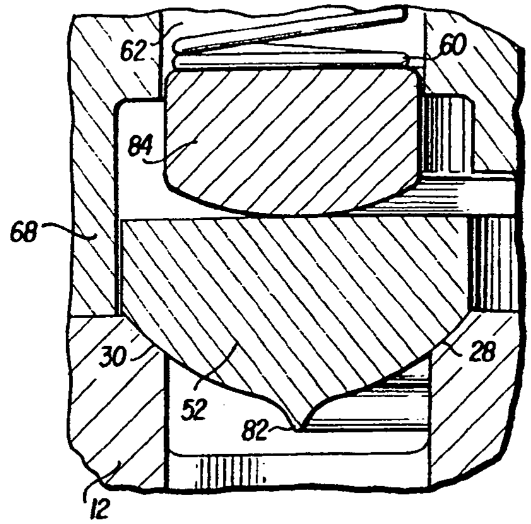


FIG. 9A

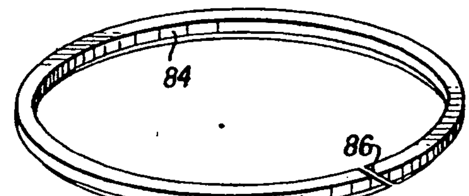


FIG. 9B

FIG. 10A

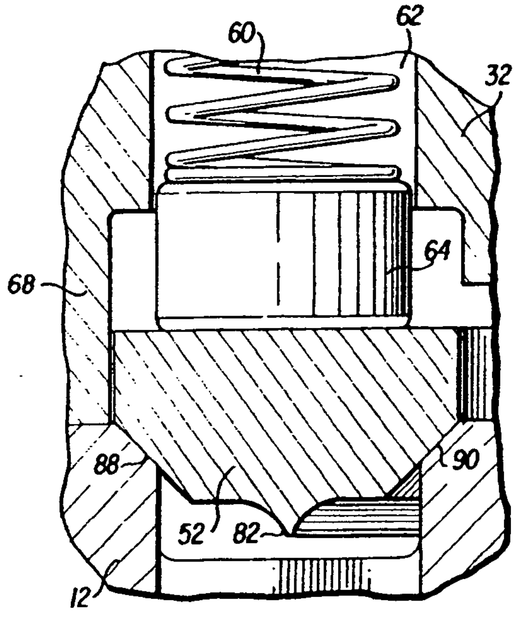
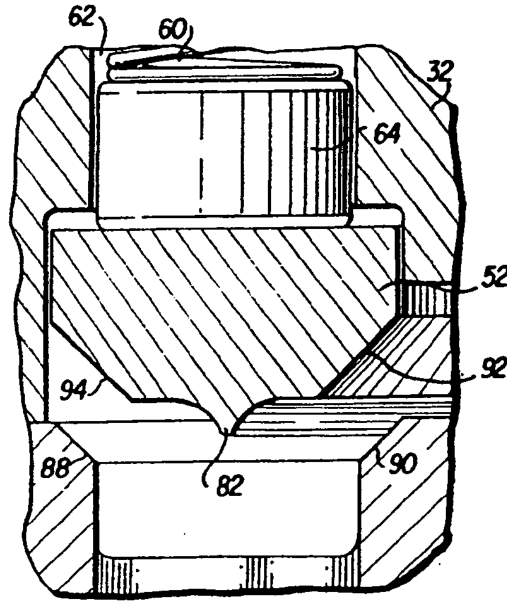


FIG. 10B



SPECIFICATION

Improved compressor valve having annular valve elements

This invention relates to valves of the type used to control fluid intake and exhaust in compressors. Particularly, the invention concerns such valves in which one or more annular valve elements are seated resiliently against corresponding spaced annular seating surfaces.

Valves of this general type have been in use for some time, as shown for example by the structure described in *Manley's* U.S. Patent No. 3,536,094 issued October 12, 1970 for a Compressor Valve. Though valves such as *Manley's* have achieved a degree of success, difficulties with this general type of valve have continued to arise.

Such valves typically are used to control the intake and exhaust of air or gas to and from the compression chambers of reciprocating compressors. The valves are spring loaded so that they open automatically when the pressure differential across the valve exceeds the closing force of the springs. At operating frequencies of 300 to 1000 cycles per minute, the pressure in the compression chambers changes very rapidly. And, since the valves are open for only a brief fraction of each cycle, they are subjected to rather high flow rates past the valve elements and potentially destructive impact velocities against neighboring structure. When liquid is entrained in the gas, even more severe impact and distortion forces may be experienced by the valve components. Large energy losses due to flow restrictions and high breakage rates for valve members, seats and springs have been common. Poor corrosion resistance, high energy losses and valve noise problems have been alleviated to an extent by valves including contoured valve elements of non-metallic materials; however, breakage of valve components has continued to be a problem. Moreover, the use of non-metallic materials such as polytetrafluoroethylene and other resinous compounds has created a new type of malfunction. Since the metallic and non-metallic components have different coefficients of thermal expansion, mismatches between the valve elements and their seats occur at elevated temperatures, leading to improper seating and attendant leakage.

An object of the present invention is to improve the flow efficiency of valves having annular valve elements by configuring the valve elements to facilitate more balanced flow past their inner and outer diameters.

A further object of the present invention is to provide a valve having annular valve elements in which impact forces are reduced by including fluidic means for dampening movement of the valve elements once the elements have moved sufficiently far from their seating surfaces.

Yet another object of the invention is to provide a valve having annular valve elements in which differential thermal expansion of the valve components is accommodated by providing the valve elements with contoured sealing surfaces and then allowing the valve elements to flex or roll as required to ensure maintenance of proper sealing contact with their associated seating surfaces.

These objects are given only by way of example, thus other desirable objectives and advantages inherently achieved by the disclosed structure may occur to those skilled in the art. Nonetheless, the scope of the invention is to be limited only by the appended claims. In one preferred embodiment of the invention, a valve apparatus comprises a valve seat having at least one fluid inlet port and at least one pair of spaced annular seating surfaces past which fluid flows when the valve is open. At least one annular valve element is provided which is shaped to seal against the annular seating surfaces when the valve is closed. A valve guard is provided which has at least one outlet port and is operatively connected to the valve seat. Between the valve element and the valve guard are located means for biasing the valve element into sealing contact with the seating surfaces. On the surface of the valve guard facing the valve elements, at least one annular cylinder means is provided which is sized to slidably receive the valve element as a piston, once the valve element has moved a certain distance away from its seating surfaces. Movement of the annular valve element into the annular cylinder fluidically dampens further movement of the valve element toward the valve guard, thereby reducing the potential for damage due to impact. Extending between the valve guard and the valve seat on either side of the annular cylinder are a plurality of axially extended, circumferentially spaced guides which constrain movement of the valve elements as the valve opens and closes.

To ensure that flow past the annular valve elements essentially is balanced, the invention also includes on each valve element an axially protruding, circumferentially extending flow balancing ridge which is positioned to fit between the spaced annular seating surfaces provided in the valve seat. Thus, as the valve moves toward and away from its seat, fluid flow is split to either side of the annular valve element, effectively reducing energy losses and distortion forces.

As indicated, the valve elements preferably are biased into contact with their seats in one embodiment of the invention. To accomplish this, a plurality of biasing springs are provided for each annular valve element, the springs being captured within a corresponding plurality of small, vented pockets provided on the underside of the valve guard. Between each spring and

its annular valve element, a force-transmitting spring button is provided, the button being sized to fit slidably as a piston within its associated spring pocket. Thus, as the valve element moves away from its seat, the spring button eventually enters its associated pocket to provide dampening in addition to that caused by compression of the valve springs and by movement of the valve element into its associated annular cylinder. To control the rate of pressure buildup in the volume captured between each annular valve element and its associated annular cylinder, flow passages may be provided from one side to the other of some or all of the spring buttons so that the annular cylinder is vented into the spring pockets. By adjustment of the number and size of such flow passages, the overall dampening effect may be varied to suit a particular application. Moreover, in some instances, the valve springs, or some of them, may be omitted so that fluidic dampening alone is achieved.

As indicated previously, the use of annular valve elements made from non-metallic materials such as polytetrafluoroethylene may engender difficulties due to the different thermal expansion coefficients of the materials of the valve element, the valve seat and the valve guard. To account for such differential expansion, the spring buttons used in the invention may be provided with rounded contact surfaces which bear against a flat surface on the annular valve elements, whereby any differential expansion may be accommodated as the valve elements are caused to flex to maintain contact with their associated seating surfaces.

Rather than using a plurality of spring buttons each captured within its individual spring pocket, the valve according to the invention alternatively may be provided with a single spring ring associated with each valve element, the spring ring being captured between the valve element and an associated biasing spring or springs. The spring ring is sized to fit slidably as a piston within an annular channel provided in the under surface of the valve guard. This, it functions to dampen movement of the valve element toward the valve guard in a manner similar to that achieved by the plurality of spring buttons. As in the case of the spring buttons, the spring ring also may be provided with flow passages from one side to the other thereof so the annular cylinder into which the valve element moves is vented into the annular channel within which the spring ring moves. Also, the spring ring may be provided with a rounded contact surface which similarly permits the valve element to flex to accommodate differential thermal expansion.

In one embodiment of the invention, the spaced annular seating surfaces are segments of a toroidal surface. This geometry particularly facilitates maintenance of adequate sealing contact upon flexure of the annular valve element due to differential thermal expansion. However, seating surfaces also may be used which are segments of conical surfaces.

The improved annular valve element according to the invention comprises an annulus of resilient material having a substantially flat upper surface and a central axis. Inner and outer edge faces of the element extend substantially parallel to its axis to meet a lower face having inner and outer downwardly extending sealing surfaces and a centrally positioned, downwardly protruded, circumferentially extended flow balancing ridge positioned between the sealing surfaces. As in the case of the seating surfaces of the valve seat, the sealing surfaces of the valve element may be segments of a toroidal surface or of a conical surface, as preferred.

In the accompanying drawings:—

Figure 1 shows a side elevation view of a compressor valve embodying the invention.

Figure 2 shows a top view of the valve illustrated in Fig. 1, particularly indicating the placement of the arcuate outlet ports and vent holes for the spring pockets.

Figure 3 shows a sectional elevation view taken along line 3–3 of Fig. 2, indicating the operative association of the valve elements with the inlet and outlet ports (right of centerline) and with the actuator springs and spring buttons (left of centerline).

Figure 4 shows a bottom view of the valve guard taken along line 4–4 of Fig. 3, indicating the relative positions of the outlet ports, spring pockets, annular cylinders and valve element guides.

Figure 5 shows a top view of the valve seat taken along line 5–5 of Fig. 3, indicating the positions of the inlet ports.

Figure 6A shows an enlarged elevation view, partially in section, of a valve element, spring button, and valve guard when the valve is closed; and Fig. 6B shows the same elements when the valve is opening. Both views are along line 6–6 of Fig. 2.

Figure 7 shows a cross-section of a valve element used in the invention and a table with typical dimensions for the various annular element sizes.

Figure 8 shows an enlarged elevation view, partially in section, of an embodiment of the invention in which the spring button has a spherical contact surface to facilitate flexing or rolling of the valve element to account for differential thermal expansion.

Figure 9A shows an enlarged elevation view, partially in cross-section, of an embodiment of the invention in which the plurality of spring buttons acting on each valve element are replaced by a single spring ring which is shown in perspective in Fig. 9B.

Figure 10A shows an enlarged elevation view, partially in section, of an embodiment of the

invention in which the valve element and valve seat have bevelled, rather than rounded, contact surfaces, the valve being closed; and

Figure 10B shows the same elements, the valve being open.

In the following description, reference is made to the accompanying drawings, the individual reference numerals identifying like elements of structure in each of the several Figures.

Referring collectively to Figs. 1 to 5, a compressor valve 10 of the type embodying the invention is illustrated. Such a valve is adapted to be used either as an intake or as an exhaust valve, the change in application of the valve being effected simply by reversing its direction of installation as will be understood by those skilled in the art. A valve seat 12 is provided which is made from a flat cylinder of steel or other suitable material having an axial or central bore 14 sized to receive a closure bolt 16. A plurality of essentially annular, radially spaced inlet ports 18, 20, 22 and 24 extend through the thickness of valve seat 12, each port comprising a plurality of arcuate segments joined by radially extending webs 26. Each port is tapered at an angle of, for example, 3 degrees toward its respective pair of radially spaced, annular seating surfaces 28, 30. See Figs. 2 and 5, in particular.

A valve guard 32 is provided which is made from a flat cylinder of steel or other suitable material also having a central bore 34 which is sized to fit over closure bolt 16. The assembly of valve guard 32 to valve seat 12 is completed by means of appropriate alignment dowels, a spacer 36 surrounding bolt 16 and a nut 38. Valve guard 32 comprises a plurality of essentially annular, radially spaced outlet ports 40, 42, 44 and 46, each port comprising a plurality of arcuate segments joined by radially extending webs 48. The outlet ports are positioned radially with respect to the inlet ports so that except for inlet port 18, each inlet port has associated with it two outlet ports. Flow from inlet port 18 passes through the valve via outlet port 40 and a plurality of axially extending bores 50 which extend through valve guard 32 around its central bore 34. See Figs. 2 and 4, in particular.

Inlet ports 18, 20, 22 and 24 are closed, respectively, by annular valve elements or seal rings 52, 54, 56 and 58. While the embodiment of the invention illustrated in the drawings includes four concentric annular seal rings, those skilled in the art will appreciate that fewer or more rings could be used, without departing from the scope of the invention. Each valve element is held against its associated seating surfaces 28, 30 by a plurality of coil springs 60 which are equally spaced about the mean circumference of the valve elements. Tapered or straight springs may be used. Each spring 60 is captured within a spring pocket 62 which is formed in the underside of valve guard 32. The outer ends of spring pockets 62 preferably are provided with vent openings 63 for purposes to be discussed subsequently. Each spring 60 bears against a spring button 64 which is sized to fit closely within its associated spring pocket 62 in the manner of a piston. Spring button 64 in turn bears upon the essentially flat upper surface 66 of its associated valve element. Movement of the valve elements from seating surfaces 28, 30 toward valve guard 32 is guided by a plurality of circumferentially spaced guide blocks 68 which extend from the under surface of valve guard 32 toward valve seat 12. Guides 68 may be provided on one or both sides of each valve element as illustrated.

The operation of a valve embodying the invention as each annular valve element moves from its closed to its fully opened position may be best understood with reference to Figs. 6A and 6B. Fig. 6A illustrates on an enlarged scale a single valve element in its closed position. As pressure builds up on the underside of the valve element, it eventually will move upward away from its associated seating surfaces 28, 30. During this movement, the valve element is guided toward valve guard 32 by circumferentially spaced, axially extended guide blocks 68, preferably located on both sides of the valve elements. As the valve element moves away from its seating surfaces, some fluid flowing past the element is permitted to move past spring button 64 through one or more axial grooves 70 provided on its sides. This fluid flows into spring pockets 62 from which it escapes via vent openings 63. By adjusting the size of or omitting openings 63, the overall dampening effect can be varied. In some cases, springs 60 may be omitted as well, so that only pneumatic effects are relied on to return the valve elements to their seats. Since spring button 64 acts as a piston within pocket 62, it tends to compress the fluid caught in the spring pocket, resulting in an pneumatic or fluidic dampening of the movement of the spring button and, in turn, of the annular valve element. Depending upon the number and size of axial grooves 70, this dampening effect can be varied as described. Or, grooves 70 may be omitted and the clearance between the spring button and its pocket may be chosen to provide the desired dampening effect. As the valve element approaches the top of its stroke, it enters an annular trough or cylinder 72 provided on the underside of valve guard 32, as shown in Fig. 6B. The fluid caught in the volume defined between the valve element and annular cylinder 72 then is compressed to provide an additional dampening effect. Of course, eventually, the fluid does leak off through axial grooves 70 and vent holes 63. The overall result is to reduce impact velocities, should the valve element actually hit the valve guard.

Turning now to Fig. 7, it is seen that valve elements 52 to 58 preferably have the same cross-section. An annulus of resilient material such as polytetrafluoroethylene or the like is used which

may be machined, molded or manufactured in any convenient manner. Typical dimensions for a valve according to the invention which has five seal rings are shown in the table. In one actual embodiment, the radial width T of the seal ring was 12 mm, and the sealing surfaces 74, 76 were configured as segments of a torus having a diameter A and a cross-sectional radius R of approximately 7.5 mm. Edge faces 78, 80 extend essentially parallel to the axis of the torus. The downwardly extending sealing surfaces 74, 76 preferably terminate in a centrally positioned, downwardly protruded, circumferentially extended flow balancing ridge 82; however, the ridge is not mandatory. Ridge 82 begins at a distance h' of approximately 7.3 mm below the torus center, and ends at a distance h of approximately 7.0 mm below the upper surface 66 of the valve element. The tip radius r was approximately 0.254 mm and the root radius r' was approximately 2.3 mm. Flow balancing ridge 82 preferably is continuous around the mean circumference of the ring and centered between its inner and outer circumferences as illustrated in Fig. 7. In operation, ridge 82 tends to split the flow of fluid coming through its associated inlet port into two approximately equal streams which flow past the seal ring without generating substantial distorting forces.

Fig. 8 shows a feature of the invention which ensures that adequate sealing contact between the valve elements and their associated seating surfaces can be maintained even though differential thermal expansion may be experienced between the valve elements and the surrounding components of the valve. As mentioned previously, the valve element material and the metal of the adjacent components have different coefficients of thermal expansion. Typically, the valve element will tend to expand more than the metal components. Thus, in the situation illustrated in Fig. 8, ring 52 would tend to expand more toward the right than would valve seat 12 and valve guard 32. Were it not for the specially configured spring button 64 used in this embodiment of the invention, this differential movement of the valve components would tend to cause improper seating of the valve elements and attendant leakage. However, valve button 64 is provided with a rounded, preferably spherical contact surface 65 where it meets upper surface 66 of the seal ring. This rounded contact surface permits the valve element to flex in such a manner that the outer edge of the ring rotates upward through an angle α and the inner edge drops a corresponding amount. Thus, the seal ring tends to roll slightly in its seat and maintain good sealing contact. The provision of the torus shaped portions of seating surfaces 28, 30 and sealing surfaces 74, 76 of course facilitates the rolling movement.

Figs. 9A and 9B show a further embodiment of the invention in which the individual spring buttons 64 are replaced by a single spring ring 84 which is sized to move as a piston within an annular channel provided in the under surface of valve guard 32. In Fig. 9A, this annular channel appears as the lower portion of spring pocket 62. Spring ring 84 may be a solid ring or may be split to allow for expansion and contraction as indicated at 86 in Fig. 9B. Also, though not illustrated in Figs. 9A and 9B, spring ring 84 may include passages similar to flow passages 70 provided in spring buttons 64.

Figs. 10A and 10B illustrate the open and closed positions of a further embodiment of the invention in which seating surfaces 28, 30 and sealing surfaces 74, 76 are no longer curved but are simply bevelled so that they are segments of conical surfaces. This embodiment of the invention is therefore somewhat simpler and less expensive to manufacture than the previously described embodiments. Otherwise, it functions identically to them.

Materials for construction of the invention may be chosen from the following alternatives:

Valve Component	*Preferred Materials*	*Suitable Alternatives*
Valve seat 12, valve guard 32, bolt 16	Steel Alloy Steels Stainless Steels Cast Iron	Aluminum Copper Copper Alloys Nickel Alloys
Valve elements 52, 58 Spring buttons 64 Spring Ring 84	Synthetic Resins (may contain particles and/or fibers of glass, carbon, bronze molybdenum, and the like	Steel Alloy Steels Stainless Steels Aluminum Copper Copper Alloys Nickel Alloys

Having described our invention in sufficient detail to enable those skilled in the art to make and use it, we claim:

CLAIMS

1. An improved valve apparatus, comprising:

a valve seat having at least one fluid inlet port and at least one pair of spaced annular seating surfaces past which fluid moves when the valve is open;

at least one annular valve element shaped to seal against said seating surfaces when the valve is closed;

a valve guard having at least one outlet port, said guard being operatively connected to said valve seat;

means cooperating with said valve guard and said valve element for biasing said valve element into sealing contact with said seating surfaces; and

annular cylinder means located in said valve guard for slidably receiving said valve element as a piston, when said valve element has moved away from said sealing surfaces, in order to fluidically dampen movement of said valve element toward said valve guard.

2. Apparatus according to Claim 1, further comprising means for guiding said at least one valve element from said seating surfaces to said annular cylinder means.

3. Apparatus according to Claim 1, wherein said at least one annular valve element comprises an axially protruding, circumferentially extending flow balancing ridge positioned to fit between said at least one pair of spaced annular seating surfaces, whereby fluid fow is split to either side of said annular valve element when the valve is opened.

4. Apparatus according to Claim 1, wherein said biasing means comprises at least one spring, pocket means in said valve guard for receiving said spring, at least one spring button captured between said annular valve element and said spring, said spring button being sized to fit slidably within said pocket means as a piston, in order further to dampen movement of said valve element toward said valve guard.

5. Apparatus according to Claim 4, wherein said pocket means is vented and said at least one spring button comprises flow passages from one side to the other thereof, whereby said annular cylinder means is vented into said pocket means.

6. Apparatus according to Claim 4, wherein said at least one spring button has a rounded contact surface with said at least one annular valve element, whereby differential expansion of said valve seat, said valve element and said valve guard may be accommodated as said valve element is caused to flex to maintain contact with said seating surfaces.

7. Apparatus according to Claim 1, wherein said biasing means comprises at least one spring, at least one annular channel in said valve guard, at least one spring ring captured between said annular valve element and said at least one spring, said spring ring being sized to fit slidably within said annular channel as a piston, in order to further dampen movement of said valve element toward said valve guard.

8. Apparatus according to Claim 7, wherein said at least one annular channel is vented and said at least one spring ring comprises flow passages from one side to the other thereof whereby said annular cylinder means is vented into said at least one annular channel.

9. Apparatus according to Claim 7, wherein said at least one spring ring has a rounded contact surface with said at least one annular valve element, whereby differential expansion of said valve seat, said valve element and said valve guard may be accommodated as said valve element flexes to maintain contact with said seating surface.

10. Apparatus according to Claim 1, wherein said seating surfaces are segments of toroidal surfaces.

11. Apparatus according to Claim 1, wherein said seating surfaces are segments of conical surfaces.

12. Apparatus according to Claim 2, wherein said guiding means comprises a plurality of circumferentially spaced guide blocks extending between said valve seat and said valve guard on at least one side of said at least one annular valve element.

13. Apparatus according to Claim 1, wherein there are a plurality of said valve elements, said valve seat having at least one inlet port for each of said valve elements; and said valve guard having at least one outlet port located radially inwardly of each of said valve elements and at least one outlet port located radially outwardly of each of said valve elements.

14. An improved annular valve element comprising an annulus of resilient material having a substantially flat upper surface and a central axis, inner and outer edge faces extending substantially parallel to said axis and a lower face extending from said edge faces and having inner and outer downwardly extending sealing surfaces and a centrally positioned, downwardly protruded, circumferentially extended flow balancing ridge positioned between said sealing surfaces.

15. An element according to Claim 14, wherein said inner and outer sealing surfaces are segments of a toroidal surface.

16. An element according to Claim 14, wherein said inner and outer sealing surfaces are segments of conical surfaces.

17. An improved valve apparatus, comprising:

a valve seat having at least one fluid inlet port and at least one pair of spaced annular seating

surfaces, past which fluid moves when the valve is open, said surfaces being segments of a toroidal surface;

at least one annular valve element shaped to seal against said seating surfaces;

a valve guard having at least one outlet port, said guard being operatively connected to said valve seat;

means for resisting movement of said valve element from said seating surfaces toward said valve guard, said means comprising at least one rounded contact surface with said valve element, whereby differential expansion of said valve seat, said valve element and said valve guard may be accommodated as said valve element is caused to flex to maintain contact with said seating surfaces.

18. Apparatus according to Claim 17, wherein said resisting means comprises at least one spring, pocket means in said valve guard for receiving said spring, at least one spring button captured between said annular valve element and said spring, said spring button comprising said rounded contact surface and being sized to fit slidably within said pocket means as a piston, in order to dampen movement of said valve element toward said valve guard.

19. Apparatus according to Claim 17, wherein said pocket means is vented and said at least one spring button means comprises flow passages from one side to the other thereof.

20. Apparatus according to Claim 17, wherein said resisting means comprises at least one spring, at least one annular channel in said valve guard, at least one spring ring captured between said annular valve element and said at least one spring, said spring ring being sized to fit slidably within said annular channel as a piston, in order to dampen movement of said valve element toward said valve guard.

21. Apparatus according to Claim 20, wherein said at least one annular channel is vented and said at least one spring ring comprises flow passages from one side to the other thereof.

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